In The United States Patent And Trademark Office

In Re Application: Tianqing He et al.

Filing Date: 11/15/03 Examiner: Jiping Lu

Serial No: 10/714,471 Art Unit: 3749

Invention: Device And Method For Rapid Drying Of Porous Materials

AFFIDAVIT

NOW COMES the undersigned, who affirms and says:

1. My name is Ali Regimand. I am the president of InstroTek, Inc. and a co-inventor for the Device and Method for Rapid Drying of Porous Materials filed in the United States Patent Office with Serial #10/714,471.

2. The Vacuum Drying Apparatus and Method disclosed and claimed in serial #10/714,471 has been successfully manufactured and marketed as the "CoreDry' by InstroTek, Inc., the company which I am President. The CoreDry is priced at $4910 per unit and since its marketing launch in 2004, my company has sold a total of 120 units. The volume for this product is expected to quadruple in the next 3 years because of the newly developed ASTM standard, described below, and Department of Transportation Specifications currently being developed in many of the states.

3. CoreDry does not have a price advantage over other vacuum dryer models on the market because the CoreDry, to my knowledge, is the only vacuum dryer for porous materials like asphalt currently being sold. The CoreDry has been successful in the market because it represents an advance in the art and has provided the users a fast and more accurate method of testing asphalt samples.

4. Attached as Exhibit A is the newly developed American Society for Testing and Materials (ASTM) standard practice, specifically developed for the CoreDry. To my knowledge, there are no other ASTM specifications for other Vacuum Drying Apparatus, since there are no other vacuum devices or processes available for asphalt drying.

ASTM International is one of the largest voluntary standards development organizations in the world for development of technical standards for materials, products, systems, and services. Standards developed at ASTM are the work of over 30,000 ASTM members. These technical experts represent producers, users, consumers, government and academia from over 100 countries.

ASTM standards are accepted worldwide by public and private agencies. In fact, some agencies will not allow the use of an equipment, process or material without an ASTM specification.

Due to the newly developed ASTM standard, CoreDry is now a process that is internationally recognized in the asphalt testing field. This standard further validates CoreDry as a new and useful process for accurate and fast drying of porous asphalt samples.

5. Attached as Exhibit B are procedures established in Colorado, Pennsylvania and a test report from Colorado regarding the CoreDry. We also know that Florida and Alabama are currently developing specifications for the CoreDry, with others states following close behind. These documents and specifications further independently validate the CoreDry technology and the advance in the art represented by the CoreDry technology and patent application, serial #10/714,471.

THE AFFIANT, first being warned that willful false statement and the like are punishable by fine, imprisonment, or both under Title 28 U.S.C. 1001, states that the above information is true except those things stated on information and belief and as to those things the undersigned believes them to be true.

This the 13th day of September, 2006

Ali Regimand, President
InstroTek, Inc.

Designation: D 7227 – 06

Standard Practice for Rapid Drying of Compacted Asphalt Specimens Using Vacuum Drying Apparatus[1]

This standard is issued under the fixed designation D 7227; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers the process of drying compacted asphalt specimens using vacuum drying apparatus.

1.2 The specimens dried by this practice remain at room temperature, which helps in maintaining specimen integrity during the drying process.

1.3 This practice can be used for compacted cylindrical and cubical bituminous laboratory and field specimens

1.4 This practice can also be used for drying other construction materials such as concrete, soils, aggregates and loose asphalt mixtures. Use manufacturers recommendations for drying other construction materials.

1.5 The values stated in SI units are to be regarded as the standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 5361 Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing

3. Significance and Use

3.1 Specimen dry weight is a critical measure in determination of accurate density and many other tests in the construction and raw materials industries. Drying specimens at room temperature is required for some tests and provides an advantage for other tests to ensure the integrity and to preserve the characteristics of specimens.

3.2 This practice covers drying compacted asphalt specimens in a vacuum chamber that is capable of keeping the specimen at close to room temperature. A vacuum pump reduces the pressure inside the chamber, thus allowing water to evaporate at low temperature. Since the specimen naturally cools during the evaporation process, making water harder to evaporate, it is important to have proper temperature controls in the chamber to ensure specimen remains at close to room temperature. Automatic controls within the unit allow the specimen to remain at close to room temperature by periodically allowing a flow of warm air to enter the vacuum chamber. Cycling between vacuum and airflow conditions allows the specimen to dry in a short period of time. Completely saturated specimens with over 30 g of retained water can be dried in about 30 minutes. For most field cores that are not completely saturated the drying time is generally less than 15 minutes.

NOTE 1—Cycle time (period) can depend on the material composition. Each cycle involves an alternating period of 30 to 180 seconds of vacuum operation and 30 to 120 seconds of air flow.

3.3 This method can be used for 100 mm diameter, 150 mm diameter cylindrical, and cubical compacted bituminous specimens.

3.4 This method can also be used for drying loose asphalt mixtures, aggregate samples and other solid specimens. Follow manufacturers recommended procedures for drying specimens other than compacted bituminous specimens.

3.5 This method can be used to determine moisture content and amount of water loss during drying by weighing the sample before and after the drying operations.

4. Apparatus

4.1 Absorptive cloth or paper towels, for drying water from surface of the specimens.

4.2 *Vacuum Chamber*, with a pump capable of evacuating a sealed and enclosed chamber to a pressure of 6 mm Hg, when at sea level. The chamber shall be large enough to accommodate specimens of 150 mm width or diameter and 180 mm in height. The device shall have an automatic vacuum, airflow and temperature control features to ensure proper drying of the specimen at close to room temperatures. Automatic controls of

[1] This practice is under the jurisdiction of ASTM Committee D04 on Road and Paving Materials and is the direct responsibility of Subcommittee D04.21 on Specific Gravity and Density of Bituminous Mixtures.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

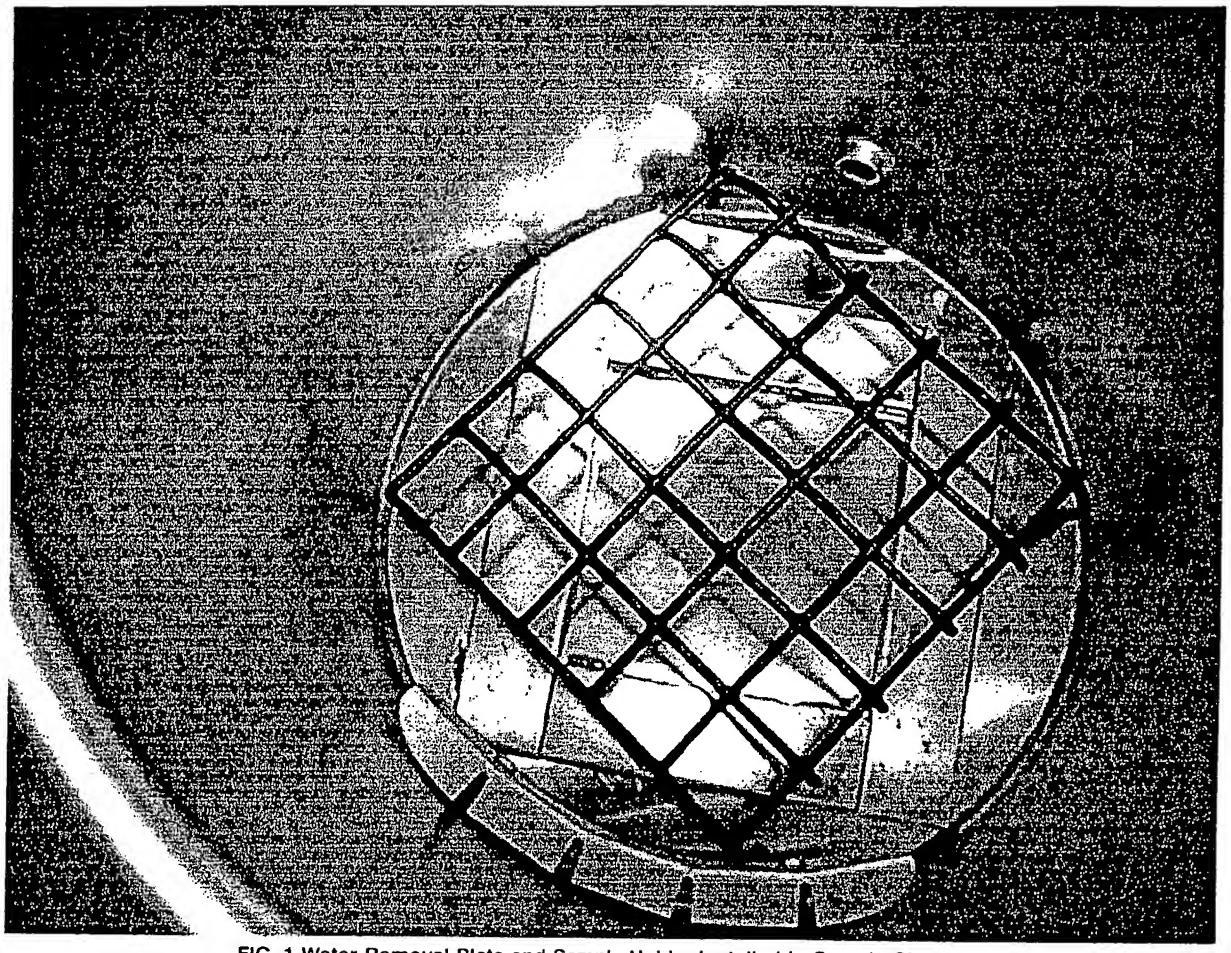


FIG. 1 Water Removal Plate and Sample Holder Installed in Sample Chamber

the unit shall be calibrated by the manufacturer prior to initial use. The device shall have the capability to display vacuum readings in the chamber and number of cycles.

4.3 *Water Removable Plate*, used for removing free water from the bottom surface of the specimen chamber.

4.4 Electronic cold trap with an airflow divider plate, used for trapping water and stopping it from entering the vacuum pump.

4.5 A handheld infrared temperature sensor accurate to ±5°C for measuring surface temperature of the specimens.

5. Sampling

5.1 Test specimens may be molded from laboratory prepared specimens or taken from the pavement in the field. Field specimens should be obtained in accordance with Practice D 5361.

6. Test Specimen

6.1 To speed up the drying process, keep and maintain the specimens to be dried between 15 °C and 30°C.

6.2 If desired, specimens may be separated from other pavement layers in accordance with D 5361.

7. Procedure

7.1 *Turn On the Unit:*

Plug the unit in a power outlet and turn on the on/off switch. Follow manufacturers recommendations for warm up and self test procedures.

7.2 *Daily Test:* Everyday before starting the testing operation, dry the cold trap and the specimen chamber. Run the unit without any specimens. The pressure reading on the display should be 6 mm Hg. or less. If the indicated pressure is higher than 6 mm. Hg, check the system for items that might need service, such as oil level and quality, seals, or water in the chamber. Refer to the manufacturer's trouble shooting instructions for obtaining a proper pressure reading in the chamber. For drying other construction materials, follow manufactuer's recommendations for pressure requirements in the chamber.

7.3 *Drying Specimens:* Use a handheld infrared thermometer to ensure that the surface temperature of the specimen is between 15°C and 30°C. If the specimen is below 15°C or above 30°C, place the specimens in a room temperature environment until the surface temperature approaches the required testing temperature of 15°C to 30°C.

7.3.1 Use paper towel or an absorptive cloth to remove any standing water from the surface of the specimen.

7.3.2 Place the specimen on top of the specimen support plate inside the chamber.

7.3.3 Place the lid on the vacuum chamber and press the lid down to ensure secure contact between the lid and the chamber. Press the appropriate key, for example the Start key, to begin the drying process.

7.3.4 When the specimen is dry, the unit will automatically stop. The unit is calibrated at the factory to sense a "dry specimen condition". Dry specimen condition is determined at the factory for the pressure at which no water remains in the chamber. During testing, the unit continuously reads the pressure inside the chamber and checks this pressure against the "dry specimen condition" pressure determined during factory calibration. Follow manufacturer's procedure for calibrating the device to dry specimen condition.

NOTE 2—Sample is considered dry when the measured weight after vacuum drying process is 0.2 grams or less of 24-hour oven drying at 50°C.

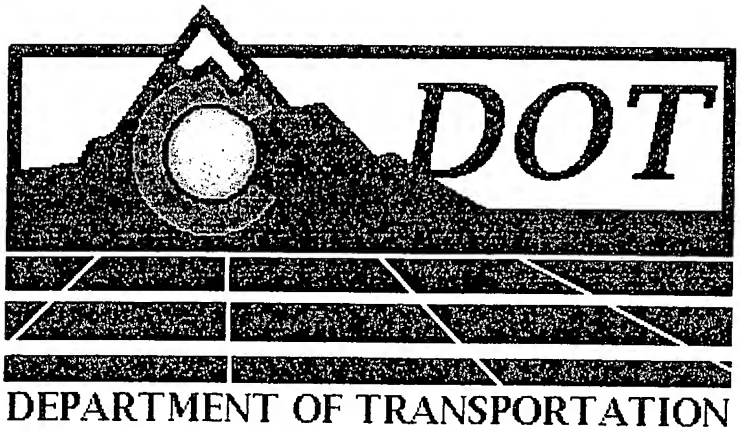
7.4 *Electronic Cold Trap:* Liquid and ice, or both, will accumulate in the cold trap as specimens are drying. Between drying specimens and for faster drying, it is best to remove the cold trap lid and the airflow divider plate and wipe out any free standing water in the cold trap. Always place the divider back into the cold trap before drying the next specimen.

8. Report

8.1 Report the following information:

8.1.1 At the end of the drying process, report the ending pressure in mm Hg, to the nearest 0.1 mm Hg, and total number of cycles displayed on the screen. This information may be used by the manufacturer or the user for trouble shooting the device, if needed.

Review and Research of Instrotek's "CoreDry®" Report



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PROBLEM TITLE

Using the CoreDry® to rapidly dry field cores for obtaining bulk specific gravity values.

PROPOSED WORK PLAN

Problem Statement - Colorado DOT currently oven dries field cores for obtaining bulk specific gravity values. This method is both slow and destructive to the cores. Cores can take up to 24 hours to dry before the dry weight of the core can be taken for the Gsb (Bulk Specific Gravity) calculation. In order to properly dry cores according to CP 44 (modified AASHTO T 166), Method B, cores must be placed in an oven at 230° F and broken down, essentially destroying the core so immersed wet and surface dry weights can no longer be taken.

The CoreDry® offers two advantages over the conventional oven drying method. First, the CoreDry® only takes 15 minutes to dry a core. The current procedure calls for a minimum of 5 hours and as much as 24 hours. Gsb values are often not available the same day a core arrives in the laboratory and project personnel usually must wait overnight for test results. Secondly, the CoreDry® does not destroy the cores. This means the surface dry and submersed weights can be rerecorded if a mistake was made in this process. The cores can also be tested by multiple laboratories if there is a testing dispute.

1. **Research Objectives** – The primary objective of this research is to simply evaluate if the CoreDry® compares well enough with the conventional oven dry method for use on projects.

2. **Research Plan** - The following steps will be taken to accomplish the objectives of the study.
   - **A.** Review literature including manufacturer's data as well as other sources that have used or researched the product.
   - **B.** Conduct testing on cores using both methods and record the results.
   - **C.** Analyze data and write report.

D. Present to MAC for approval, rejection or more investigation.

3. **Research Plan** – In order to meet the objectives of this research extensive testing must be conducted on numerous cores. One constraint on the research is the amount of time we have to do the testing. The CoreDry® device we are using to conduct the research is on loan from Instrotek and needs to be returned before November 2005. Regions 3 and 5 have volunteered to conduct the testing on project cores and if time permits the central lab will also conduct testing on cores in the lab.

   There is not a set amount of cores that will be tested. As many cores as possible will be tested before the CoreDry® must be returned. There are also no parameters on the cores such as aggregate grade, binder grade etc. Both 4-inch and 6-inch cores will be included in the study.

   After all of the results are recorded the Gsb of both procedures will be compared for statistical analysis. Any sort of bias in either method will also be investigated.

4. **Implementation** – If the results in this research are found to be favorable this may be accepted as an approved product and an alternative procedure to the conventional oven drying method. An alternative procedure in CP 44 will also be drafted.

LITERATURE REVIEW

The CoreDry® apparatus is currently only a couple years old. As a result there has not been very much research conducted on the device and there is not very much literature available for review. Other than the manufacturer's product information there has not been anything published by any transportation agency on the CoreDry®.

Joyce Stone of the Indiana DOT conducted research in the spring of 2005 on the device and was trying to publish the findings in the fall of 2005 in the Transportation Research Board Journal. Her findings are somewhat promising for the CoreDry® but her research did reveal a couple potential problems with the CoreDry®. In a draft report she stated "BSG results using the vacuum method were more consistent and generally higher than those using the standard oven drying method." According to her findings the CoreDry® is precise but not necessarily accurate. Last word is that the research has been dropped and will not be published any time soon.

The Maryland Department of Highways conducted a brief unpublished study comparing the CoreDry® to a fan dry method. It appears as though the fan dry method consists of the cores sitting in front of a fan for at least 8 hours. The CoreDry® outperformed the fan method in their study.

TESTING PARAMETERS AND CONSIDERATIONS

For proper and accurate testing as well as evaluation of test results some basic parameters need to be considered and or assumed.

For this study field cores used on projects will be tested. The cores density will first be determined by the CoreDry® method and then by the conventional oven dry method. The CoreDry® method must always be done first since the oven dry method destroys the cores. As a result of this always being the case a bias is anticipated in the results. The CoreDry® will dry most of the water out of and off of the core initially. The oven will then dry the remaining water. This may cause a bias in the results by allowing one method to "pretreat" all the cores for the next method it is being compared to. The bias occurs because the oven dry cores have already been dried once by the CoreDry®. The cores will likely not take on much more water for the oven dry method especially if they were already bulked before the CoreDry® dried them out the first time. This pretreating could mean that the cores can only become more dry than they were before making it seem as though the oven dry cores are always less dense than they were before when taking the dry weight.

TEST RESULTS

A summary of the test results are below in Table 1.

Table 1: Summary of Results

Core #	Size	Thickness	CoreDry Bulk SPG	CP-44 Bulk SpG	Bulk SpG Difference	CoreDry Dry Wt. (g)	CP-44 Dry Wt. (g)	CoreDry Density (%)	CP-44 Density (%)	Density Difference (%)
1	4"	3"	2.31[illegible]	2.309	0.002	1041	1040.1	95.6	95.5	0.1
2	4"	3"	2.309	2.307	0.002	955.8	955	95.5	95.4	0.1
3	4"	3"	2.29	2.288	0.002	951	950.2	94.7	94.6	0.1
4	4"	3"	2.287	2.285	0.002	750.5	749.8	94.6	94.5	0.1
1	4"	3"	2.26[illegible]	2.256	0.005	1171.4	1168.8	92.6	92.4	0.2
2	4"	3"	2.259	2.254	0.005	1190.6	1188.3	92.5	92.3	0.2
3	4"	3"	2.33	2.327	0.003	13[illegible]2.2	13[illegible]0.3	95.5	95.3	0.2
4	4"	2 3/4"	2.302	2.297	0.005	1140.9	1138.6	94.3	94.1	0.2
5	4"	2 1/2"	2.31[illegible]	2.307	0.004	1044.8	1043.2	94.7	94.5	0.2
6	4"	3"	2.372	2.368	0.004	1200.7	1199	97.2	97	0.2
7	4"	2 1/2"	2.29[illegible]	2.286	0.006	1043.8	104[illegible]	93.9	93.6	0.3
1	6"	2"	2.13[illegible]	2.[illegible]33	0.005	1761.9	1757.6	88.4	88.2	0.2
2	6"	2"	2.21[illegible]	2.204	0.007	1940.8	1935.1	91.4	91.2	0.2
3	6"	2"	2.22	2.216	0.004	1888.2	1885.1	91.8	91.6	0.2
4	6"	2 1/2"	2.172	2.[illegible]67	0.005	2164	2159.4	89.8	89.6	0.2
5	6"	2 3/4"	2.197	2.[illegible]92	0.005	2474.8	2469.2	90.9	90.7	0.2
6	6"	2 3/4"	2.22	2.216	0.004	2600.8	2595.5	91.8	91.6	0.2
7	6"	3"	2.197	2.[illegible]93	0.004	2941.3	2936.1	90.9	90.7	0.2
8	6"	2 1/2"	2.238	2.234	0.004	2403.8	2395.9	92.6	92.4	0.2
1	4"	2 1/4"	2.32	2.316	0.004	908.9	907.8	95.9	95.7	0.2
2	4"	2 1/4"	2.3[illegible]	2.306	0.004	875.1	873.6	95.5	95.3	0.2
3	4"	2 1/4"	2.24[illegible]	2.237	0.004	887.6	886.1	92.6	92.4	0.2
4	4"	2 1/4"	2.315	2.312	0.003	907.3	906.2	95.7	95.5	0.2
5	4"	2 1/4"	2.254	2.25[illegible]	0.004	858.9	857.6	93.1	93	0.1
6	4"	2 1/4"	2.266	2.263	0.003	924.5	923.2	93.6	93.5	0.1
7	4"	2 1/4"	2.264	2.261	0.003	886.5	885.5	93.6	93.4	0.2
1	6"	2 1/4"	2.282	2.279	0.003	2068.1	2065.8	94.3	94.2	0.1
2	6"	2 1/4"	2.19[illegible]	2.[illegible]89	0.002	2078.6	2075.8	90.5	90.5	0
3	6"	2 1/4"	2.204	2.202	0.002	2274.4	2272.2	91.1	91	0.1

Table 1 (Continued): Summary of Results

Core #	Size	Thickness	CoreDry Bulk SPG	CP-44 Bulk SpG	Bulk SpG Difference	CoreDry Dry Wt. (g)	CP-44 Dry Wt. (g)	CoreDry Density (%)	CP-44 Density (%)	Density Difference (%)
4	6"	2 1/4"	2.285	2.284	0.001	2262.6	2261.7	94.4	94.4	0
5	6"	2 1/4"	2.164	2.158	0.006	2023.9	2018	89.4	89.2	0.2
6	6"	2 1/4"	2.244	2.241	0.003	2237.2	2234.1	92.7	92.6	0.1
7	6"	2 1/4"	2.227	2.224	0.003	2130.7	2127.8	92	91.9	0.1
8	6"	2 1/4"	2.26	2.258	0.002	2267.5	2265.2	93.4	93.3	0.1
14851-1	4"		2.374	2.373	0.001	1436.0	1435.1	96.1	96.1	0
14851-2	4"		2.350	2.349	0.001	1436.1	1435.2	95.2	95.1	0.1
14851-3	4"		2.386	2.382	0.004	1212.6	1210.2	96.6	96.4	0.2
14851-4	4"		2.386	2.384	0.002	1041.6	1040.8	96.6	96.5	0.1
14851-5	4"		2.390	2.388	0.002	1991.1	1990.3	96.8	96.7	0.1
14851-6	4"		2.398	2.397	0.001	1161.1	1160.9	97.1	97.0	0.1
14851-7	4"		2.382	2.381	0.001	1820.5	1820.3	96.4	96.4	0
14851-8	6"		2.285	2.28	0.005	2215.6	2211.6	92.5	92.3	0.2
14851-9	6"		2.248	2.247	0.001	2215.6	1982.5	91.0	90.8	0.2
14851-10	6"		2.223	2.215	0.008	2215.6	1646.4	89.7	89.7	0
14851-11	6"		2.224	2.221	0.003	2215.6	2282.5	89.8	89.7	0.1
14851-12	6"		2.220	2.218	0.002	2215.6	2454.4	89.6	89.5	0.1
14851-13	6"		2.244	2.24	0.004	2215.6	2133.2	90.6	90.4	0.2
14851-14	6"		2.170	2.169	0.001	2215.6	2164.9	87.6	87.6	0
14851-15	6"		2.258	2.256	0.002	2215.6	2900.1	91.2	91.1	0.1
14851-16	6"		2.256	2.254	0.002	2215.6	2269.8	91.1	91.0	0.1
14851-17	6"		2.206	2.204	0.002	2215.6	2958.5	89.1	89.0	0.1
14851-18	6"		2.201	2.199	0.002	2215.6	3073.1	88.9	88.8	0.1
14851-19	6"		2.198	2.196	0.002	2215.6	2030.7	88.7	88.7	0
14851-20	6"		2.256	2.253	0.003	2215.6	3202.8	91.1	91.0	0.1
14851-21	6"		2.190	2.187	0.003	2215.6	2619.8	88.4	88.3	0.1
14914-1	4"		2.250	2.255	-0.005	856	856.5	94.5	94.6	-0.2
14914-2	4"		2.311	2.304	0.007	748.6	747.5	97.2	96.9	0.3
14914-3	4"		2.237	2.233	0.004	788.8	787.2	94.1	93.9	0.2
14914-4	4"		2.279	2.276	0.004	960.9	959.8	95.8	95.7	0.1

Table 1 (Continued): Summary of Results

Core #	Size	Thickness	CoreDry Bulk SPG	CP-44 Bulk SpG	Bulk SpG Difference	CoreDry Dry Wt. (g)	CP-44 Dry Wt. (g)	CoreDry Density (%)	CP-44 Density (%)	Density Difference (%)
14914-5	4"		2.236	2.234	0.002	355	353.6	94	93.5	0.1
14914-6	4"		2.320	2.307	0.013	824.8	824.2	97.6	97	0.6
14914-7	4"		2.260	2.254	0.006	803.6	802.7	95	94.8	0.2
14914-1*	4"	1 7/8"	2.232	2.22	0.012	709.8	707.6	93.4	92.9	0.5
14914-2*	4"	2"	2.287	2.275	0.012	779.7	778.2	95.7	95.2	0.5
14914-3*	4"	2"	2.286	2.253	0.013	749.8	747.9	94.8	94.2	0.6
14914-4*	4"	2"	2.227	2.218	0.009	793.6	792.4	93.2	92.8	0.4
14914-5*	4"	1 7/8"	2.259	2.243	0.016	702.9	701.3	94.5	93.8	0.6
14914-6*	4"	1 7/8"	2.239	2.238	0.011	787.3	786.3	93.2	93.7	0.5
14914-7*	4"	2"	2.231	2.279	0.012	776.7	775.1	95.9	95.4	0.5
1467[illegible]-1	6"	1 7/8"	2.296	2.293	0.003	1869.9	1868.2	94.3	94.1	0.2
1467[illegible]-2	6"	1 7/8"	2.229	2.226	0.003	1847	1844.4	91.9	91.8	0.1
1467[illegible]-3	6"	2"	2.288	2.287	0.001	1735.6	1734.3	93.5	93.5	0
1467[illegible]-4	6"	1 3/4"	2.284	2.282	0.002	1508.9	1507.5	93.4	93.3	0.1
1467[illegible]-5	6"	1 5/8"	2.296	2.295	0.001	1495.4	1494.4	94.3	94.2	0.1
1467[illegible]-6	6"	1 7/8"	2.310	2.309	0.001	1730.9	1729.9	95.3	95.2	0.1
1467[illegible]-7	6"	2"	2.284	2.281	0.003	1646.8	1644.6	93.4	93.2	0.2
			Average	0.004					Average	0.1

*Cores on project 14914 were bulked by two different testers for the CoreDry® and the Oven Dry method

ADDITIONAL TESTING AND RESULTS

After the initial testing was concluded and the results recorded in Table 1, additional testing was needed to examine if the bias is an outcome of the circumstances or if the oven dry method is actually more effective than the CoreDry® method.

The additional research was conducted to try and take out the bias or the advantage the oven dry method has by always going after the CoreDry® method. Twelve samples were put under a vacuum for 90 seconds and saturated with water much like the Moisture Susceptibility test in Colorado Procedure 5109. The weight of the sample was taken before saturation, after saturation and then again after the sample was dried. This determined how effective each method is in removing water from the samples. The two methods were then compared in how efficient they are in removing water as a percentage.

While conducting the extra testing the CoreDry® did not appear to completely dry some of the samples. The weight was noted and the sample was dried again. This may not be anything major since the CoreDry® is not designed to dry vacuum saturated design samples and the apparatus may have been overloaded but it may have to be written into the procedure to check the core for any residual water on the surface and dry the core again if moisture is visible.

Table 2: Results for Extra Testing with the CoreDry®

CoreDry						
Sample Number	Original Weight (g)	Saturated Weight (g)	Water Added (g)	Dried Weight (g)	Water Removed (g)	Efficency (%)
391-1	1168.6	1183.2	14.6	1169.5	13.7	93.8%
391-2	1168.4	1181.9	13.5	1169.1	12.8	94.8%
391-3	1169.5	1184.1	14.6	1170.5	13.6	93.2%
399-1	1165.6	1176.9	11.3	1167.3	9.6	85.0%
399-2	1165	1176.1	11.1	1166.8	9.3	83.8%
399-3	1165.8	1176.6	10.8	1167.7	8.9	82.4%
400-1	1144.9	1155.6	10.7	1146.7	8.9	83.2%
400-2	1145	1155.9	10.9	1146.7	9.2	84.4%
400-3	1144.8	1154.9	10.1	1146.6	8.3	82.2%
406-1	1155.1	1161.1	6	1155.9	5.2	86.7%
406-2	1154.6	1160.3	5.7	1155.4	4.9	86.0%
406-3	1154.2	1163.4	9.2	1155.3	8.1	88.0%
					Average	86.9%

Table 3: Results for Extra Testing with the Oven

Oven Dry								
Sample Number	Original Weight (g)	Pan Tare (g)	Saturated Weight (g)	Water Added (g)	Pan+ Sample (g)	Dried Weight (g)	Water Removed (g)	Efficency (%)
391-1	1168.6	249.3	1183.4	14.8	1419.1	1169.8	13.6	91.9%
391-2	1168.4	248.4	1182.2	13.8	1418	1169.6	12.6	91.3%
391-3	1169.5	254.9	1184.6	15.1	1425.7	1170.8	13.8	91.4%
399-1	1165.6	251.9	1177.7	12.1	1418.4	1166.5	11.2	92.6%
399-2	1165	254.7	1176.5	11.5	1420.4	1165.7	10.8	93.9%
399-3	1165.8	244.6	1177.4	11.6	1411.4	1166.8	10.6	91.4%
400-1	1144.9	248.7	1157.8	12.9	1394.7	1146	11.8	91.5%
400-2	1145	252.1	1157.7	12.7	1398.2	1146.1	11.6	91.3%
400-3	1144.8	255.1	1155.5	10.7	1401	1145.9	9.6	89.7%
406-1	1155.1	251.4	1161.4	6.3	1407.1	1155.7	5.7	90.5%
406-2	1154.6	256.9	1160.7	6.1	1412.2	1155.3	5.4	88.5%
406-3	1154.2	254.4	1164.2	10	1409.6	1155.2	9	90.0%

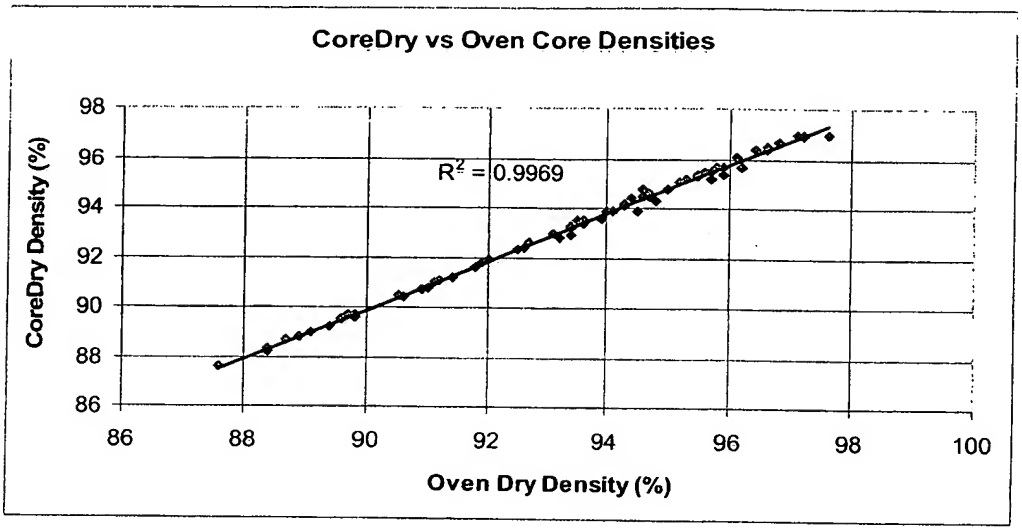
Average	91.2%

RESULTS SUMMARY

When comparing field cores the average difference in density comes out to be 0.17% and never exceeded a difference of 0.6%. The average Bulk Specific Gravity difference is .004 and never exceeded .016. When conducting the extra testing on design samples the CoreDry® removed 86.9% of the water added while the oven removed 91.2%.

The densities between the two methods were plotted below and an "R" squared value was determined to be .9969.

Chart 1: CoreDry® Versus Oven Dry Densities



A T_{paired} Test was conducted on the densities and showed no statistical difference between the two methods.

t paired = d bar / (Sd /sq rt n)

d bar = 3.76 / 76 = .0495

Sd squared = 3.76 - (13^2/76) = 1.536

Sd = 1.239

Sq rt n = sq rt 76 = 8.718

t paired = .0495/(1.239/8.718)=.3483

T .05, 76 ≡ 1.668

Since .3483 is less than 1.668, the data strongly suggests there is no difference in densities.

CONCLUSION

Based on the data analysis it is recommended that the CoreDry® apparatus be accepted as an alternative to the oven dry method (Method B) of CP 44.

Commonwealth of Pennsylvania
Department of Transportation

PA Test Method No. **715LA**
Revised Feb. 2006
5 Pages

Method of Test for

DETERMINATION OF BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS ROADWAY CORE SAMPLES

1. SCOPE

1.1 This method of test is intended for determining the bulk specific gravity of bituminous roadway core samples obtained for and governed under the Local Acceptance specification only.

2. TEST SPECIMEN

2.1 Core samples from the compacted pavement obtained in accordance with PaDOT methods of sampling a compacted roadway.

2.2 Specimen size – It is recommended, (1) that the diameter of the cored specimen be at least equal to four times the nominal maximum size of the aggregate; and (2) that the thickness of the core be the actual depth of the material as placed on the project or at least 1.5 times the nominal maximum aggregate size.

2.3 Specimens shall be free of foreign materials such as seal coat, tack coat foundation material, soil and any other material not a component of the original mix.

2.4 Sample Preparation

2.4.1 Specimens are to be separated from other pavement layers by sawing or other suitable means. Care shall be exercised to ensure separation does not damage the specimen.

2.4.2 Specimens shall be dried to a constant mass (constant mass shall be defined as the mass that is obtained when further drying does not alter the observed mass by more than 0.05 percent) using one of the procedures described:

(1) Dry the sample for at least 20 hours at 52 ± 3°C (125 ± 5°F), checking the dry weight at two hour intervals until constant mass is reached.

(2) Dry the sample in a large, flat pan of known mass in an oven at 110 ± 5°C (230 ± 9°F) until the fine aggregate-asphalt portion can be separated into pieces no larger than 6.4 mm (1/4 in.). Return the sample to the oven, checking the dry weight after cooling to room temperature [25 ± 5°C (77 ± 9°F)], every half hour until constant mass is attained on at least three consecutive weighings. Note: Caution should be exercised before using this method since the sample will be destroyed by this process. Samples coated with paraffin cannot be prepared by this method.

(3) Dry the sample by exposure to moving air of relatively low humidity while changing the orientation of the sample frequently and checking the dry weight every half hour until constant mass is attained on at least three consecutive weighings.

(4) Dry the sample in a vacuum drying apparatus meeting the requirements of, and in accordance with, ASTM D-7227-06.

2.5 Verification

2.5.1 Use methods 2.4.2(3) and 2.4.2(4) as preparation for acceptance testing only after verification in accordance with the appropriate specification.

VOLUMETER METHOD

3. APPARATUS

3.1 Weighing Device – Conforming to the requirements of AASHTO M-231, Class G2.

3.2 Thermostatically controlled water bath designed to maintain the bath temperature at 25 ± 0.5°C (77 ± 0.9°F)

3.3 Thermometer – ASTM 17C (17F), having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C (0.2°F) subdivivsions

3.4 Volumeter – Calibrated, 1.2L or an appropriate capacity depending on the sze of the sample.

4. PROCEDURE

4.1 Immerse the specimen in the water bath and saturate for at least 10 minutes. At the end of the 10 minute period, fill a calibrated volumeter with distilled water at 25 ± 1°C (77 ± 1.8°F). Place the saturated specimen into the volumeter and bring the temperature of the water in the volumeter to 25 ± 1°C (77 ± 1.8°F). Cover the volumeter making certain that some water escapes through the capillary bore of the lid. Wipe the volumeter dry and weigh the volumeter and contents to the nearest 0.1 gram.

4.2 Remove the sample from the volumeter, quickly damp dry the saturated specimen with a damp towel, and as quickly as possible weigh the specimen. Any water that seeps from the specimen during the weighing operation is considered a part of the saturated specimen. Dry the specimen to a constant mass (Sec. 2.4.2) and weigh to the nearest 0.1 gram.

Note: If desired, the sequence of testing operations can be changed to expedite the procedure by first determining the dry weight, then the weight of the saturated specimen in the volumeter and the mass of the saturated specimen.

5. CALCULATIONS

5.1 Calculate the dry basis bulk specific gravity (reported to three decimal places) as follows:

$$GSm = WSm / \{(0.997\ g/mL) \times [VVo - (1.003mL/g) \times (WT - WSa - WVo)]\}$$

GSm = bulk specific gravity at 25.0°C (77°F)
WSm = mass of the dry specimen (grams)
VVo = volume (mL) of the volumeter at 25.0°C (77°F) to the nearest tenth mL.
WT = total mass (gm) of the volumeter, saturated specimen, and water in the volumeter at 25.0°C (77°F).
WSa = Mass (gm) of the saturated specimen.
WVo = Mass (gm) of the volumeter.

5.2 Calculate the percent water absorbed (reported to one decimal place) as follows:

$$\% Abs. = (WSa - WSm) / \{(0.997\ g/mL) \times [VVo - (1.003mL/g) \times (WT - WSa - WVo)]\} \times 100$$

If the percent water absorbed is greater than 3.0 percent, use the procedure for coating the specimen with melted paraffin and the calculations described in PTM 716.

SUSPENSION METHOD

6. APPARATUS

6.1 Weighing Device – Conforming to the requirements of AASHTO M-231, Class G2. The balance shall be equipped with a suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of the scale pan balance. The holder should be immersed to a depth sufficient to cover it and the sample during weighing. Wire suspending the holder shall be as small as practical to minimize any possible effects of a variable immersed length.

6.2 Water bath – for immersing the specimen in water while suspended under the balance, equipped with an overflow outlet for maintaining a constant water level and designed to maintain the bath temperature at 25 ± 1°C (77 ± 1.8°F).

7. PROCEDURE

7.1 Weigh the specimen in air to determine the dry mass after it has been dried to a constant mass and allowed to return to room temperature 25 ± 5°C (77 ± 9°F).

7.2 Suspend each specimen completely in water at 25 ± 1°C (77 ± 1.8°F) for 4 minutes and record the immersed mass. Remove the sample and quickly damp dry the saturated specimen with a damp towel, and as quickly as possible weigh the specimen and record the surface dry mass. Any water that seeps from the specimen during the weighing operation is considered a part of the saturated specimen.

Note: If desired, the sequence of testing operations can be changed to expedite the procedure by first determining the immersed mass, then the surface dry mass, and then the dry mass.

8. CALCULATION

8.1 Calculate the dry basis bulk specific gravity (reported to three decimal places) as follows:

$$GSm = WSm / (WSa - WSw)$$

GSm = bulk specific gravity
WSm = Dry mass (gm) of the specimen.
WSa = Mass (gm) of the surface dry specimen.
WSw = Immersed mass (gm) of the specimen.

8.2 Calculate the percent water absorbed (reported to one decimal place) as follows:

$$\% \text{ Abs.} = [(WSa - WSm) / (WSa - WSw)] \times 100$$

If the percent water absorbed is greater than 3.0 percent, use the procedure for coating the specimen with melted paraffin and the calculations described in PTM 716.

Colorado Procedure 44-07

Standard Method of Test for

Bulk Specific Gravity and Percent Relative Compaction of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens

This procedure modifies AASHTO T 166-93. AASHTO T 166-93 or any subsequent revisions may not be used in-place of this procedure.

1. SCOPE

1.1 These test methods cover the determination of bulk specific gravity of specimens of compacted bituminous mixtures as defined in ASTM E 1547, Terminology Relating to Industrial Chemicals.

1.2 The bulk specific gravity of the compacted bituminous mixtures may be used in calculating the unit weight of the mixture.

2. REFERENCED DOCUMENTS

2.1 *ASTM Standards:*

D 2726 Test Method for Bulk Specific Gravity and Density of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens

E 1547 Terminology Relating to Industrial Chemicals

2.2 *Colorado Procedures:*

CP-L 5115 Preparing and Determining the Density of Bituminous Mixture Test Specimens Compacted by the Superpave Gyratory Compactor

3. SIGNIFICANCE AND USE

3.1 This procedure covers and describes two test methods for determining bulk specific gravity in order to calculate the percent relative compaction of Hot Mix Asphalt.

4. TERMINOLOGY

4.1 Definitions:

4.1.1 *Constant Mass* – The mass at which further drying at either temperature as noted in Section 10.4 for two hours does not alter the mass by more than 0.05 percent.

5. TEST SPECIMENS

5.1 Test specimens may be either laboratory-molded bituminous mixtures or from the bituminous pavements. The mixtures may be surface or wearing course, binder or leveling course, or hot mix base.

5.2 Size of Specimens--It is recommended, (1) that the diameter of cylindrically molded or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) that the thickness of specimens be at least one-and-one-half times the maximum size of the aggregate.

5.3 Pavement specimens shall be taken from pavements with a core drill, a diamond or Carborundum saw, or by other suitable means.

5.4 Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from pavement or mold. Specimens shall be stored in a safe, cool place.

5.5 Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

5.6 If desired, specimens may be separated from other pavement layers by sawing or other suitable means.

6. APPARATUS

6.1 *Balance* – Conforming to the requirements of AASHTO M 231, for the class of balance required for the principle sample weight of the sample being tested. The balance shall be equipped with suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of scale pan or balance.

6.2 *Suspension Apparatus* -- Wire suspending the container shall be the smallest practical size at the point where it penetrates the water's surface to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the test sample during weighing without contacting the bottom of the water bath.

6.3 *Water Bath* -- For immersing the specimen in water while suspended under the balance, equipped with an overflow outlet for maintaining a constant water level.

6.4 *Damp Towel* -- Flannel or terry cloth towel.

6.5 *Oven* – If using Method B (Rapid Test), a forced draft oven capable of maintaining 230°F ± 9° (110°C ± 5°).

6.6 *CoreDry™* – If using Method C (CoreDry™ Test), a CoreDry unit from Instrotek® Inc.

METHOD A

7. PROCEDURE

7.1 Method A shall be used for laboratory compacted specimens only.

7.2 Laboratory compacted specimens, which have not been exposed to moisture, do not require additional drying. Cool the specimen to room temperature at 77°F ± 9° (25°C ± 5°). Samples must not feel warm to the touch. Record the dry mass A. If laboratory compacted specimens are wetted before the dry mass is determined, dry them as specified in Section 10.4 once the immersed mass and surface-dry mass have been determined. Immerse each specimen in water at 77°F ± 1.8° (25°C ± 1°) for 4 ± 1 minutes and record the immersed mass, C. Remove the specimen from the water, damp dry the specimen by blotting it as quickly as possible with a flannel cloth or terry cloth towel which has been thoroughly wetted and wrung out, then immediately determine the surface-dry mass, B. The objective of blotting is to remove all of the surface water without losing any water that has been absorbed into the sample. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen.

NOTE 1: If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass (C) can be taken, then the surface-dry mass (B) and finally the dry mass (A).

8. CALCULATIONS

8.1 Calculate the bulk specific gravity of the specimens as follows (round and report the value to the nearest three decimal places):

$$\textbf{Bulk Specific Gravity} = \frac{A}{(B - C)}$$

Where:

A = Mass (in grams) of sample in air,
B = Mass (in grams) of surface-dry specimen in air,
C = Mass (in grams) of sample in water.

8.2 Calculate the percent water absorbed by

the specimen (on volume basis) as follows:

$$\text{Percent Water Absorbed by Volume} = \frac{(B - A)}{(B - C)} \times 100$$

9. RECORD

9.1 No CDOT Form, record on your own worksheet.

METHOD B (RAPID TEST)

10. PROCEDURE

10.1 Method B shall be used for pavement cores.

10.2 This procedure can be used for testing specimens, which are not required to be saved, and which contain substantial amounts of moisture. Specimens obtained by coring or sawing can be tested the same day by this method. Specimens obtained by coring or sawing shall be tested using Method B or C and shall not be tested using Method A.

10.3 The testing procedure to determine the immersed mass (C) and the surface dry mass (B) shall be the same as given in Section 7. The dry mass (A) of the specimen is determined last, as per 10.4.

10.4 Determine and record the weight of a large flat bottom drying pan and place the weighed specimen into the pan. For Forced Draft Ovens, place the pan and specimen in a 230°F ± 9° (110°C ± 5°) oven. For 5½ in. (140 mm) diameter or larger cores, or for porous or wet cores, leave the specimen in the oven until it can be easily separated into pieces not larger than 2 in. (50 mm) in diameter. Use extreme caution not to lose any portion of the original specimen while separating it. Replace the separated specimen in the oven. Document the start time. Dry all of the specimen(s) for 3 hours minimum and determine the weight at that time, (record the time). After an additional 2 hours of drying determine the weight at the time, (record the time if needed). The drying of the specimen can be stopped at this minimum of 5 total hours if constant mass is reached. Continue the drying and weighing at 2-hour intervals until constant mass is reached, up to the 24-hour maximum period. Determine the final weight of the heated specimens and use this weight as the dry mass A in the equation in Section 8.1.

METHOD C (COREDRY™ TEST)

11. PROCEDURE

11.1 Method C may be used for pavement cores in place of Method B.

11.2 This procedure can be used for testing specimens, which can be saved, and which contain substantial amounts of moisture. Specimens obtained by coring or sawing can be tested the same day by this method. Specimens obtained by coring or sawing shall be tested using Method B or C and shall not be tested using Method A.

11.3 The testing procedure to determine the immersed mass (C) and the surface dry mass (B) shall be the same as given in Section 7. The dry mass (A) of the specimen is determined last, as per 11.4.

11.4 Turn CoreDry™ to ON position. Allow the CoreDry™ to warm up and go through preparation cycles until the "System Ready" prompt appears. Allow cores to warm to room temperature and towel dry the surface of cores if there is free standing moisture on the surface. Place core on side on wire mesh in the vacuum chamber. Clean any ice or moisture out of moisture trap with a lint free cloth. Place lids on vacuum chamber and moisture trap and press START. CoreDry™ will cycle until drying is complete and chamber will pressurize so lids can be freely removed. If moisture is visible on core surface clean moisture trap and repeat drying process. Determine the final weight of the

dried specimens and use this weight as the dry mass A in the equation in Section 8.1.

12. CALCULATIONS

12.1 Calculate the bulk specific gravity as shown in Section 8.1.

12.2 Calculate percent relative compaction as follows:

$$\text{Percent Relative Compaction} = \frac{\text{Bulk Sp. Gravity}}{\text{Max. Sp. Gravity}} \times 100$$

NOTE 2: Max. Sp. Gr. information in CP 51.

12.3 Calculate the percent air voids as follows:

$$\text{Air Voids} = 100 - \text{Percent Relative Compaction}$$

12.4 Calculate the VMA as follows:

$$VMA = 100 - \frac{G_{mb}P_s}{G_{sb}}$$

Where:

VMA = Voids in mineral aggregate in percent of bulk volume,
G_{sb} = Bulk specific gravity of the aggregate,
G_{mb} = Bulk specific gravity of compacted mix,
P_s = Aggregate, percent by total weight of mix.

13. PRECISION

13.1 Duplicate specific gravity results by the same operator should not be considered suspect unless they differ more than 0.020.

14. RECORD

14.1 No CDOT Form, record on your own worksheet.